Simulated Baseline Cars

Project Number:	690705
Classification	Public
Deliverable No.:	5.2
Work Package(s):	WP5
Document Version:	1.0
Issue Date:	February, 28th 2018
Document Timescale:	
Start of the Document:	December, 01st 2017
Final version due:	January, 31st 2018.
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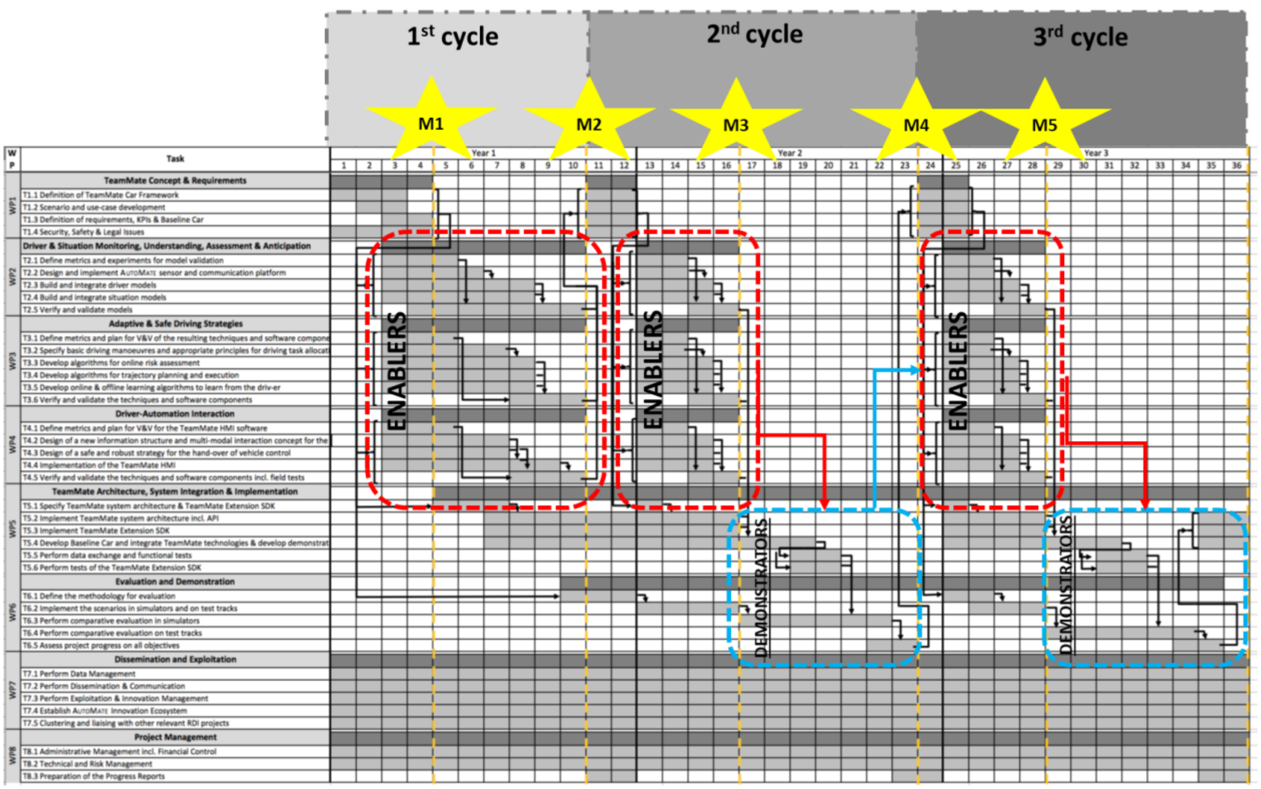
1 Introduction

The activities in the Automate project have been organized in 3 cycles to guarantee that the maturity of the technologies developed in the project is iteratively increased while assessing that the progresses are consistent with the needs of the demonstrators and, in turn, with the overall concept and objectives of the project.

As shown in, the first 2 cycles are focused on the development and technical validation of the components (i.e. the enablers) performed in WP2, WP3 and WP4. The experience acquired in the 1st cycle (lesson learnt) has been used at the beginning of the 2nd cycle to review the requirements and metrics for the design and development of the enablers and, as a consequence, to improve them.

At the end of the 2nd cycle, the enablers are planned to be integrated into the demonstrators in WP5, and the performances of the 1st version of the demonstrators are evaluated against their baseline in WP6.

In the 3rd cycle, WP2, WP3 and WP4 are fed with the results of this evaluation process to deliver the final version of the enablers. The 3rd cycle ends with the evaluation of the final version of the demonstrators.



This document is related to the activities carried out in task T5.4: in particular, the goal of this deliverable D5.2 “Simulated Baseline Cars” is to report and describe the prototype Baseline simulators.

2 Concept of the project

The top-level objective of AutoMate is to develop, evaluate and demonstrate the “TeamMate Car” concept as a major enabler of highly automated vehicles. This concept consists of considering the driver and the automation as members of one team that understand and support each other in pursuing cooperatively the goal of driving safely, efficiently and comfortably from A to B.

As a consequence, in order to show how the enablers contribute to the implementation of this concept, it is important to briefly explain why the cooperation is needed, and how the human and the automation can support each other to create a safe, efficient and comfortable driving experience.

As shown in Figure 1, both the human and the automation have **limits** that can negatively affect the safety as well as the efficiency, the comfort, the trust and the acceptance of the autonomous driving.

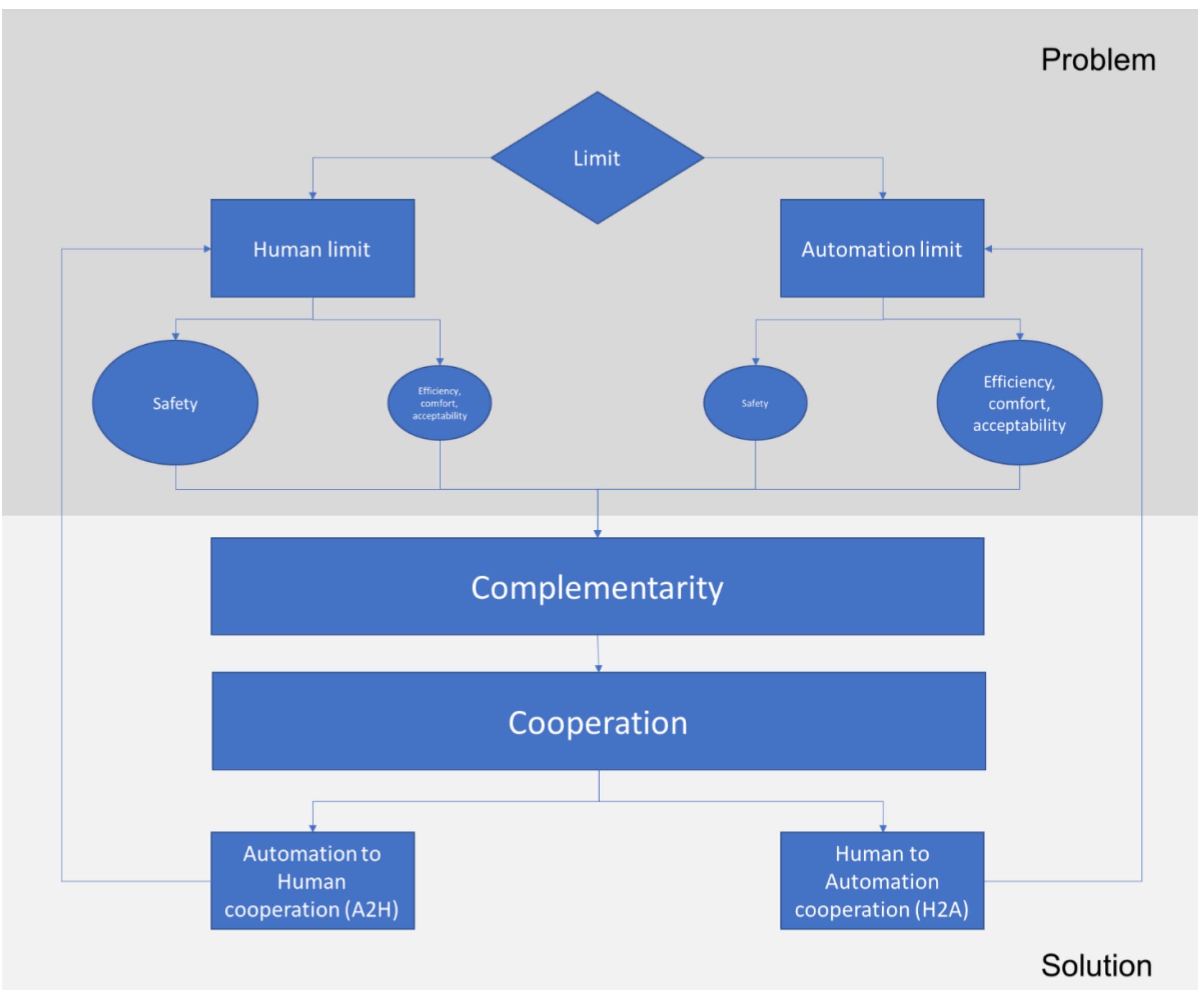


Figure 1: Schematic representation of the overall concept of the project

For the human, the limits are often related to his/her driving performance: they are likely to affect the safety, and cause accidents.
For the automation, the limits, mostly at perception and decision level, may affect the efficiency and the comfort of the trip, and then, in turn, the acceptance of the automation.
The AutoMate approach is based on the mutual complementarity between the driver and the automation: this support is achieved through the cooperation between the team members.
While the Automation to Human Cooperation (A2H) is used to complement the human limits, the Human to Automation Cooperation (H2A) is implemented to allow the driver to support the automation to overcome its limits.
The complementarity between the driver and the automation is the conceptual solution to compensate the reciprocal limitations, while the cooperation is how the complementarity is implemented. shows how both the A2H and the H2A cooperation can be implemented in perception (state A and B) and in action (state C and D).
The state machine in Figure 2 describes the project’s concept, highlighting the difference between the two approaches. Therefore, this is the means to explain how the cooperation is implemented at concept level; it should be not considered the vehicle state machine, since it serves as a means to explain the high-level vision of AutoMate: in fact, in this version of the state machine, the conditions for the transition among the states are not described.

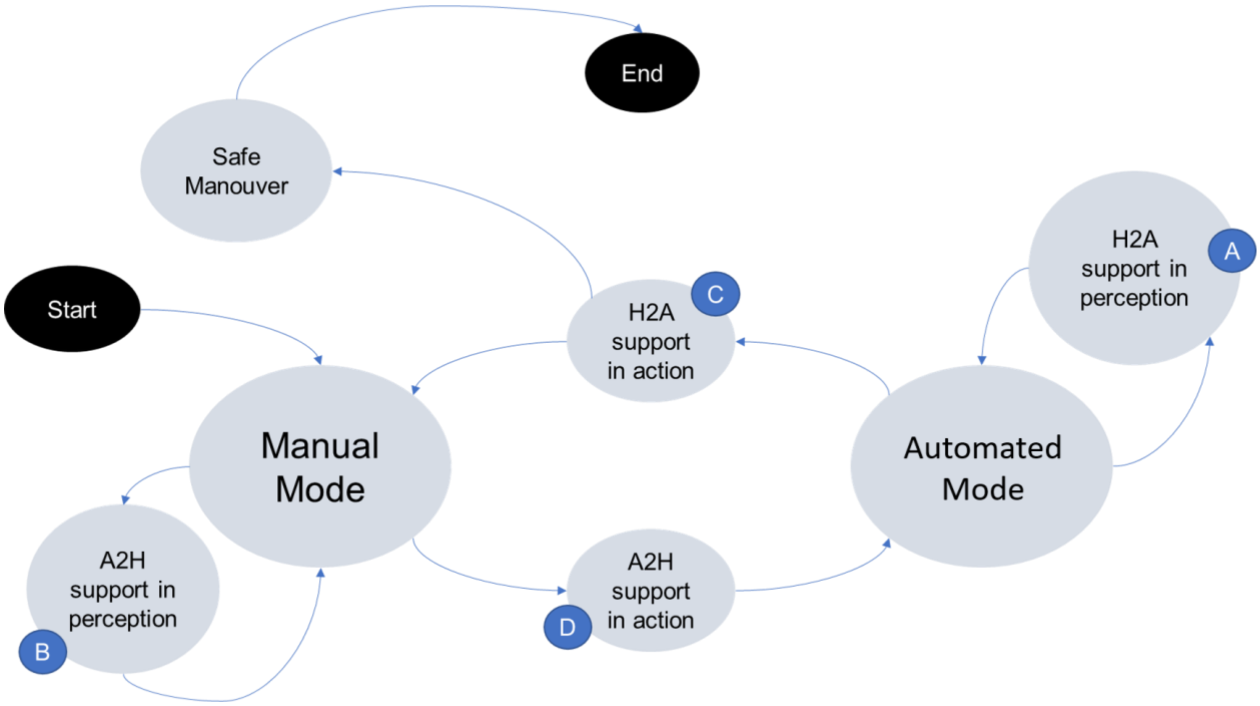


Figure 2: State machine that shows how the cooperation is implemented

The scenarios and use cases selected to demonstrate the relevance of each enabler are therefore representative and consistent with the direction of cooperation implemented by that enabler, as well as the modality of support (i.e. either in action or perception).

3 Baseline

According to the refinement of the concept, new needs emerged to represent the cases in which the different types of cooperation is required and therefore this affects also the definition and the implementation of the baseline(s).

The scenarios in which the use cases are placed are the same as the first cycle; the use cases listed below describe the four different types of cooperation, i.e. the **two directions** of the cooperation (Automation to Human and Human to Automation) and the **two levels** of the cooperation (in **perception**, which implies giving a support but staying the same state, and in **action**, which requires an active shift of the paradigm, i.e. a transition of control).

This approach, based on the theoretical framework described at the beginning of the project (cfr. D1.1), aims to implement the project's concept on the task distribution and the human-automation cooperation concepts.

3.1 ULM demonstrator (simulator)

The ULM simulator demonstrator is evaluated by considering the PETER scenario.
The PETER scenario has been identified since it is representative of a limit of the automation: in a rural road, the automation may not be able to efficiently overtake a tractor, because

1) Its sensors cannot acquire a complete view of the environment (due to the tractor)
2) The automated vehicle is not able to detect the right moment to start overtaking

As a consequence, the automated vehicle may take a lot of time before overtaking, or even do not overtake at all (and just follow the tractor along the rural road).
In order to improve the efficiency of the maneuver, the automation can ask for support to the driver (H2A, either in perception or in action).
H2A in perception aims at demonstrating how human can support automation by providing necessary input at perception level. In this use case, the demonstrator needs Peter's input to fill in missing information beyond its perceptual horizon, which is obstructed by a tractor, in order to carry out the overtaking manoeuvre in a safe manner.

In this use case, the automation is in charge of the vehicle control, and it needs a support in perception from the driver. The support in perception means that the automation needs a help to continue the driving task without a transition of control to the driver.
This use case is relevant because the disengagements represent a highly critical condition for the interaction between the driver and the automation. And, with this type of support (H2A in perception) we can reduce the number of disengagements.
The PETER scenario is also particularly relevant for the safety of the driver, because driving in two-lane two-way rural roads with low visibility (due to the tractor) can negatively affect the perception of risk of the driver, and lead to risky driving behaviors.
Therefore, for the ULM simulator demonstrator, both the use case for the support of the driver to the automation (H2A in perception) and the use case for the support of the automation to the driver (A2H in action) have been selected to evaluate the added value of the TeamMate approach (i.e. the cooperation).

The selection of both H2A support and A2H support (as well as the corresponding different use cases), requires the definition of 2 different baselines for the evaluation:

- For the H2A use case, the evaluation is aimed at demonstrating the added value of the driver, thus the baseline is the driverless approach (i.e. the autonomous driving without any intervention of the driver)
- For the A2H use case, the evaluation is aimed at demonstrating the role of the automation to promptly and efficiently address safety-critical conditions, thus the baseline is the manual driving (i.e. when there is no support of the automation)

The following text provides 2 simple stories (adapted from the PETER use cases) to intuitively describe the scenario for the evaluation of the ULM simulator demonstrator.

H2A support in perception

Starting scenario
Peter is driving in a narrow rural road in automated mode. The car, arriving behind a tractor, detects that it obstructs the view.

Baseline

The vehicle is not confident if there is oncoming traffic due to the obstructed view. The vehicle follows the tractor until its environment perception is sufficient to safely overtake automatically or if Peter takes over control and overtakes manually.

TeamMate Car

The vehicle is not confident of the oncoming traffic, due to a limit in sensory perception. Based on Peter's previous behaviour in similar situations the TeamMate car, using its intention recognition mechanism infers Peter's current intention. In case Peter has not overtaken in similar situations before, the TeamMate Car will stay behind the tractor and will not bother Peter by asking for support in overtaking. If the TeamMate Car infers that Peter normally would overtake in this situation it recognizes a conflict between Peter's inferred intention and its current capabilities. The TeamMate car asks Peter for support: Check the opposite lane as I can't see it and tell me whether I can overtake or not. After Peter has checked the lane and is sure that there is no oncoming traffic, Peter selects the overtaking maneuver which is executed in automated mode.

A2H support in action

Starting scenario
Peter is driving in a narrow rural road manually. He approaches a tractor, that causes limited visibility or the road, but he is in a hurry, so he decides to perform the overtake.

Baseline
The baseline car would let Peter overtake because he is in manual mode and the system will not interfere with him. Another car arrives from the opposite lane and a collision is likely to occur if Peter will begin the overtaking manoeuvre. If the driver is not able to come back in the initial lane, an accident is likely to occur.

TeamMate Car
The TeamMate car detects a car approaching on the opposite lane and based on Peter's previous and current behaviour the TeamMate Car, using its intention recognition mechanism assumes that Peter has the intention to overtake. In order to avoid the pending safety critical situation the TeamMate car warns Peter about the oncoming car, clearly depicting the situation to enhance Peter's understanding of the current traffic situation and explaining Peter why the TeamMate Car warns him, using its multimodal HMI.

3.2 VED demonstrator (simulator)

The VED simulator demonstrator will be evaluated by considering the MARTHA scenario.
The MARTHA scenario has been identified since it is representative of a limit of the automation: in case of roadworks, the automation may not be able to detect the lanes to safely drive in Automated Mode.
As a consequence, the automated vehicle may unexpectedly handover the control to the driver (the so called "disengagement") and this situation could represent a safety critical condition for the driver (as already explained in the previous sections).
In order to improve the efficiency of the maneuver, and avoid the disengagement, the automation can ask for support to the driver (H2A in action).
H2A in action was selected in order to demonstrate how human can support the automation when the automation reaches its functional limits. The support in action implies that one of the team member needs direct intervention by the other for a safe driving.
While the H2A use cases selected so far (for EVA and PETER) describe a support in perception, and thus are linked to efficiency, trust and acceptance issues, the H2A in action is also particularly relevant for the safety of the driver, because without his/her intervention, the TeamMate car is not able to continue driving in Automated Mode and it has to perform either a disengagement or a safe maneuver to stop the vehicle.
The MARTHA scenario is also relevant for the safety because it considers a use case where Martha is distracted, and she needs the support of the automation to guarantee her safety.
Therefore, for the VED simulator demonstrator, both the use case for the support of the driver to the automation (H2A in action) and the use case for the support of the automation to the driver (A2H in perception and in action) have been selected to evaluate the added value of the TeamMate approach (i.e. the cooperation).

The selection of both H2A support and A2H support (as well as the corresponding different use cases), requires the definition of 2 different baselines for the evaluation:

- For the H2A use case, the evaluation is aimed at demonstrating the added value of the driver, thus the baseline is the driverless approach (i.e. the autonomous driving without any intervention of the driver)
- For the A2H use case, the evaluation is aimed at demonstrating the role of the automation to promptly and efficiently address safety-critical conditions, thus the baseline is the manual driving (i.e. when there is no support of the automation).

The following text provides 2 simple stories (adapted from the MARTHA use cases) to intuitively describe the scenario for the evaluation of the VED simulator demonstrator.

H2A support in action

Starting scenario
The car is driving in an extra-urban road in Automated Mode.

Baseline
Through the sensors, the vehicle detects that the lane markings are no longer visible in about 150 meters. This implies a system boundary for the vehicle as its lateral control algorithms depend on detection of lanes. Hence, the vehicle decides that it cannot continue the trip safely and issues a take-over request (TOR) 6 seconds[2] before disengaging. A late TOR is likely to affect the safety and the acceptance of the system negatively.

TeamMate Car
Through the V2I communication, it detects that there are road works in 1 kilometer. Since the TeamMate car knows that it will not be able to deal with this situation in automated mode, it asks Martha for a support in action: in particular, it asks Martha to handle vehicle control through the road work zone. Martha is attentive, and she takes over vehicle control until the end of the roadworks, when the TeamMate car can shift back to Automated Mode.

A2H support in perception and in action

Starting scenario
Martha is driving in Manual Mode. She receives an incoming call.

Baseline
The baseline vehicle (full manual) is not able to detect her distraction. Martha’s distraction may, thus, affect the safety of the trip.

TeamMate Car
The TeamMate car detects that she is distracted, so it informs her about the risk she is running. However, she does not care about the warning, and keeps talking animatedly on the phone. So, the TeamMate car informs her that it will take the control of the vehicle in a few seconds, and then it automatically shifts to Automated Mode.

[2] At 90 km/h, a distance of 150 meters corresponds to 6 seconds.

3.3 CRF/REL demonstrator (simulator)

The selection of the H2A use case as the most relevant for the evaluation (to demonstrate the added value of the cooperation in the EVA scenario) also affects the definition of the baseline for the CRF/REL demonstrator. Since the demonstrator is aimed to show the value of the driver to support the automation, the baseline is represented by a condition where the driver has no role in the cooperation (i.e. the so called "driverless" approach): therefore, the baseline is the autonomous driving without any support of the driver.

The baseline has been defined by considering the elements that show the benefits of the TeamMate car against the baseline itself in the EVA scenario.

In particular, the benefits of the TeamMate car are:

- the vehicle could reduce the time that is needed to enter the roundabout (and, as a consequence, the frustration of the driver)
- The support in perception is able to increase the effectiveness of the trip
- the cooperation is able to improve the comfort and the acceptance

The following text provides a simple story (adapted from the EVA use cases) to intuitively describe the scenario for the evaluation of the CRF/REL demonstrator where the baseline will be used.

H2A support in perception

Starting scenario
The car is driving in Automated Mode.

Baseline
When it approaches a roundabout, it detects high traffic flows. The car waits a lot before entering the roundabout, since (like Google car), it needs a relevant threshold of space to perform the manouver (see https://www.youtube.com/watch?v=Cnyq26N5tg0). The car enters the roundabout after a lot of time, causing as a consequence relevant frustration to Eva.

TeamMate Car
When it approaches a roundabout, it detects high traffic flows that can affect the efficiency (i.e. the TeamMate car evaluates that it may take some time to

enter the roundabout in Automated Mode). To speed up the maneuver, the TeamMate car asks Eva a cooperation in perception, asking her to check the available space and to provide a trigger to start the maneuver. Eva checks the traffic and gives the confirmation to enter the roundabout. The TeamMate car understands the feedback and enters the roundabout in Automated Mode.

4 Architecture

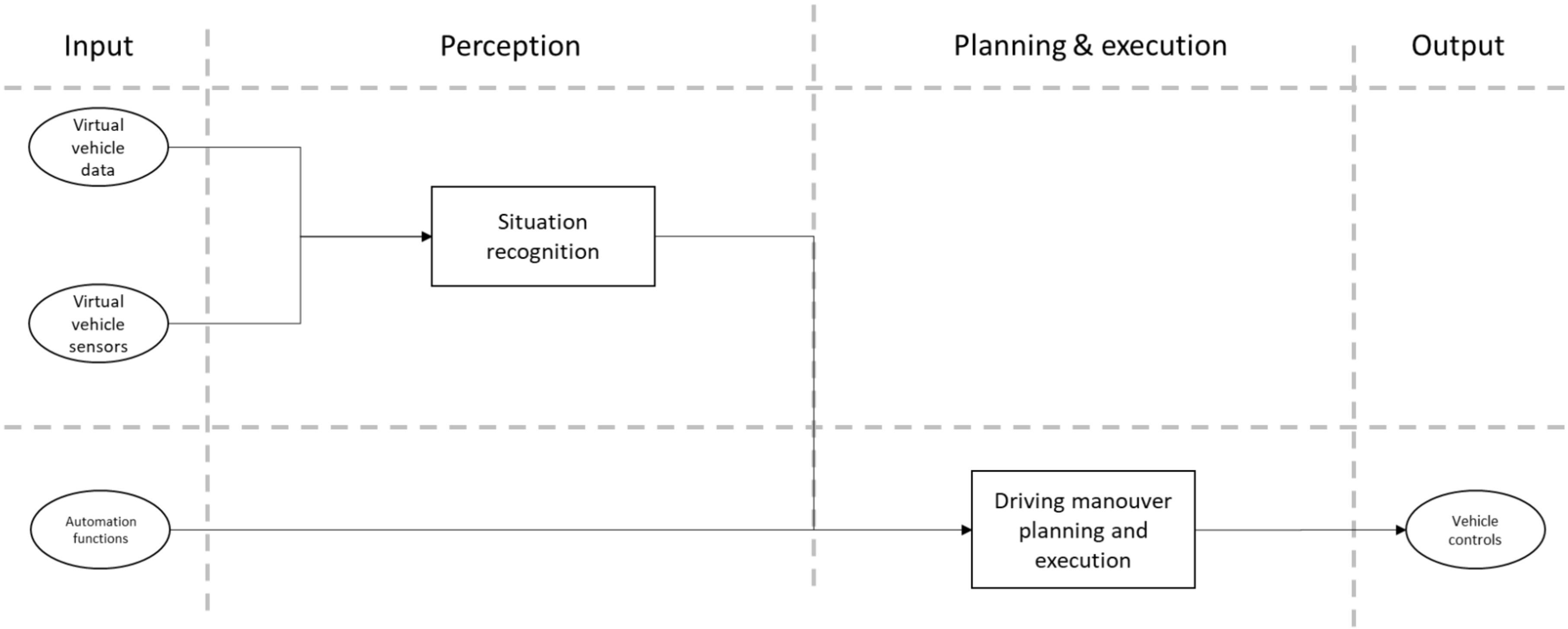


Figure 3. Automated baseline architecture

Since in this cycle only driving simulators will be considered, the architecture of the automated baseline foresees 3 demonstrators with a common high-level structure, i.e. a driving simulator able to drive autonomously also in complex scenarios.

The architecture represented in Figure 3 describes the implementation of the enablers of automation. The virtual vehicle data, and the environment data obtained through virtual vehicle sensors are used to increase the awareness of the vehicle about the surrounding environment.
After this perceptual level, the manouver is planned and executed by the automation; the final output is the vehicle control performed by the automation.

5 Implementation

5.1 ULM simulator

The baseline for the ULM Demonstrator is a car defined as a highly automated vehicle SAE level 3, without any TeamMate features. This baseline will be used for evaluation against the TeamMate car features, which will be implemented in a simulator and a real vehicle. This allows the testing of various developments, e.g. HMI-versions, which can all be implemented in the simulator and only partly in the vehicle due to hardware restrictions. Therefore, in the following sections we divide into the simulator and vehicle implementations.

For the evaluation of the TeamMate car features, the baseline will be implemented in the ULM driving simulator using. The driver will be able to interact with the system through a central touch panel. This GUI allows the user to choose between different actions via touch buttons on a very simple GUI in the central stack.
The baseline will be implemented in the ULM driving simulator with the SILAB driving simulation engine. The simulator is a mock-up that represents a real car (as shown in Figure 4) with a driver and a passenger seat. Additionally, there are several features in the driving simulator:

- steering wheel (force-feedback)
- pedals
- indicators
- central touch panel
- displayed rear mirrors (central, left, right)
- Smart-eye camera (static eye tracking system)

It also includes three high definition beamers that project the simulated environment onto a projection screen in front of the driver to create an immersive driving environment (as shown in Figure 5).

Figure 4 ULM driving simulator

Figure 5 ULM car Mock-up inside projection screen

It will be used to implement both baselines (automated and manual driving), because the software configuration for SILAB simulator includes an automation component, that allows the implementation of automated scenarios. This automation is configurable so most TeamMate features can be implemented to test the overall concept against the baseline automated car.

5.2 VED simulator

VED has a static driving simulator composed of 4 x 32” screens displaying a total of 120° of horizontal field of view (as shown in Figure 6) while rear view is displayed by using three other screens. The driving simulator runs on Oktal’s SCANeR™ studio software.

Figure 6 VED driving simulator

It will be used to implement both baselines (automated and manual driving), because the software configuration for SCANeR™ studio software includes the following components, that allows the implementation of automated scenarios:

- 1 x SCANeR™studio Essential - Cluster configuration
- 1 x Terrain (3D environment edition + GeoData Import)
- 1 x Traffic and pedestrian model
- 1 x Driver module with basic human driver model and hardware interface with eye-tracker and physiological sensors
- 1 x Automated driving module

- 1 x CALLAS module to edit vehicle dynamics

1 x Europe v2 Driving environment representative of all road types in European countries

5.3 CRF/REL simulator

The baseline has been implemented in the driving simulator of REL based on a SCANeR™studio 1.6 driving simulation engine. It is a 1-driver front passenger simulator with real controls and automotive parts:

- steering wheel
- pedals
- ergonomic seat

It also includes a 50″ wide-screen monitor to create an immersive driving environment (as shown in Figure 7).

The software configuration for SCANeR™studio 1.6 includes the following components, that allows the implementation of automated scenarios:

- 1 x SCANeR™studio Essential - Cluster configuration
- 1 x ADD-ON Terrain (3D environment edition + GeoData Import)
- 1 x TRAFFIC & PEDESTRIAN MODEL
- 1 x ADD-ON AUTONOMOUS VEHICLE
- 1 x CALLAS Car RunTime (included in SCANeR™studio Essential)
- 1 x SENSORS
- 1 x FFB INTERFACE (compliant with TRW Steering Wheel)
- 1 x Occulus Rift Plugin
- 1 x BASIC DRIVING ENVIRONMENTS (5 units - included in SCANeR™studio Essential)

Figure 7 CRF/REL driving simulator

6 Conclusion and future Steps

The TeamMate system architecture has the aim of defining a common structure for the implementation of the innovative TeamMate Car concept in car simulators. In particular, it allows the integration of all enablers (i.e. enabler 1-6) into 5 demonstrators with different characterises (3 simulators and 2 vehicles).

The TeamMate system architecture also takes into consideration that the initial versions of the enablers, as developed in WP2-4, have to be tailored according to the needs of each specific demonstrator.

By starting from the framework defined in WP1 (included in D1.1 and D1.3) and the initial architecture defined in the Grant Agreement (shown in **Error! Reference source not found.**), the building blocks have been progressively replaced by the concrete enablers selected for each demonstrator.

Moreover, APIs and SDKs have been implemented to easily reuse, modify and extend the TeamMate components as well as access real-time data by third parties. These APIs and SDKs are an important enabler of the AutoMate ecosystem, because it will allow third parties to exploit the potential of AutoMate to create innovative applications.

Once the enablers have been selected for each demonstrator, the next steps will mainly regard the tailoring of these enablers and the implementation of concrete mechanisms to share data.

To tailor the enablers resulting from the WPs 2, 3 and 4 to the real needs of the demonstrators, the following steps will be carried out:

1. Definition of interfaces between enablers and demonstrators: which information is exchanged between each enabler and demonstrator and how
2. Implementation of connectors and methods to share data: implementation of the mappings defined in previous steps.

Finally, as pointed out, this document is focused on the implementation in driving simulator; next deliverable, D5.3 "TeamMate Car Demonstrator after 2nd Cycle" will deal with the description of the TeamMate Car into the prototype vehicles foreseen in the project.